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Application of Effective Microorganism (EM) in Food Waste Composting: A review

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ABSTRACT

Objective: This paper provides a review on the application of effective microbe (EM) in food waste composting. It emphasized on the application EM in composting method, the EM properties and the quality of compost with EM in terms of nutrient content and heavy metals concentration.

Method: This paper reviewed all related articles on EM from 2000 to 2014. All of the articles were searched through Scopus and Google Scholar search engines using specific keywords related to the topic.

Result: EM has a great potential to be applied on food waste composting as it can accelerate the composting process and reduce odor during the decomposition of organic material.

Conclusion: EM has a great potential to be used in accelerating the composting process and increased nutrient in compost. EM controls the temperature and reduces pathogens in the compost to produce good quality of compost. However, detail assessment is needed to assess the effect of EM application on compost quality and the safety for human health.

Keywords: *Effective microorganisms, food waste, nutrient, heavy metals, composting*

1. Introduction

Food waste management is one of the global environmental issues. Over 97% of food waste is estimated to be buried in landfills in the United State (Levis et al., 2010). In certain countries such as Japan and Korea, landfilling of food waste has been banned and this has led to food waste separation from the municipal solid waste (MSW) (Kim et al., 2011). Proper management and recycling of food waste is also a challenge in most of developing countries including Malaysia (Khoo et al., 2010; Bernstad and Cour Jansen, 2011). Leachates in landfills are formed from the decomposition process of organic material in the food waste (Behera et al., 2011; 2010) and produces toxic elements such as aromatic compounds, halogenated compounds, phenols, pesticides, heavy metals and ammonium and these pollutants gives effect on the survival of aquatic life forms, ecology and food chains leading to enormous problems in public health. These detrimental health problems include carcinogenic effects, acute toxicity and genotoxicity (Mukherjee et al., 2015).

Composting is a sustainable alternative method in managing food waste as it produces bio-fertilizers, relatively low air and water pollution, have low operational cost and have the ability to generate income for their products (Taiwo, 2011; Lleo et al,, 2013; Li et al., 2013). The composting process decomposed organic matter by microorganism under certain moisture, aerobic or anaerobic conditions to produce a product in a form of powder (i.e. the compost) which are stable, low in moisture and free from pathogen (Soares et al., 2013). The product from composting process can be applied directly to soil as bio-fertilizer that contain nutrients such as potassium, nitrate, sodium, calcium, magnesium, and chloride for plant grow (Khan and Ishaq, 2011).

However, one of the issues in composting process is the long duration of time that is required to complete the process. For example, a small-scale organic matter composting using windrow method took three to four months to produce compost (Awasthi et al., 2014; Patidar et al., 2014). Another issue with composting is the emission of unpleasant odors because of the trace volatile organic compounds and fine aerosols arising as a consequence of volatilization of compounds contained within kitchen wastes formed during decomposition process. The unpleasant odour was much stronger when the compost was in acidic conditions compared to when it was in neutral or alkaline (Chen et al., 2012; Sundberg et al., 2013). The unpleasant odor has significant effects to human health because the hydrogen sulphide (H_2S) gas in the odors is highly toxic, produces an offensive irritating rotten egg odor and the emission may reduce the quality of life. It may lead to the death when the concentration reaches 200 ppm (Du et al., 2014).

Compost also contains heavy metals such as Cd, Pb, Cr and Zn that can potentially pollute soil and plant (Chen et al., 2010; Singh and Kalamdhad, 2011). These elements may accumulate in human body through vegetables uptake from soil and can produce adverse effect to human health via the food chain. Exposure of heavy metals may cause blood and bone disorders, kidney damage, decreased mental capacity and neurological damage (Chen et al., 2010; Mohee and Sobbhany, 2014; Page et al., 2014; Singh et al., 2011).

Effective microbe or microorganisms (EM) is a type of microbial inoculant developed by Teruo Higa (1970s). The application of EM in compost production was proven to accelerate composting process (Saravanan et al., 2013; Sharma et al., 2014; Mbouobda et al., 2014). The rate of conversion of food waste into compost was accelerated to 45 days due to the inoculation of effective microorganisms when compared to the natural process of aerobic digestion which took two months (Saravanan et al., 2013). Study done in India found that paddy straw treated with EM and compost inoculant hasten the composting process by bringing C:N ratio down to 15:1 and achieving a total humus content of 4.82 % within 60 days and show high activity of hydrolytic enzyme and microbial activity (Sharma et al., 2014). EM greatly accelerated the breakdown (mineralization) of the organic matter in the Bokashi as well as in the soil which later release more nutrients into the soil as nutrients to plants for growth (Mbouobda et al., 2014).

EM is commercially available. The technology has been distributed to over 90 countries in the world. In general, EM suspension contains a group of microorganisms, in particular, lactic acid bacteria, yeast, and photosynthetic bacteria, which are mainly used in agriculture (EM Research Organization, 2014). Two more species of microorganisms were found in EM suspension namely as fermenting fungi and actinomycetes (Talaat, 2014). These microorganisms have specific function. For example, bacteria producing lactic acid inhibit the growth of pathogenic microorganisms and other various microorganisms by reducing the pH through lactic acid production. Yeast produces many biological active agents such as amino acids and polysaccharides which feed other microbe. The phototrophic bacteria involved in various metabolic systems play a major role in nitrogen cycle and carbon cycle. The application of EM to the soil or plant ecosystem also can improve soil quality and soil health. It also encourages the plant growth, increase the yield and improve the quality of crops (Hu and Qi, 2013; Mowa and Maass, 2012; Javaid and Shah, 2010).

Several studies have showed that EM is produced from organic waste such as kitchen and fruit waste (Sarju et al., 2009; Muhammad Firdaus, 2007; Ismail et al., 2012). A 24-hour interval up to 3 days was taken to produce EM from the kitchen waste (Muhammad Firdaus, 2007). The homemade EM has the potential to reduce phosphate and nitrate in the palm oil waste effluent (Sarju et al., 2009). In addition, the homemade EM produced from kitchen waste reduced the Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, phosphate and sulphate in the industrial wastewater treatment (Muhammad Firdaus, 2007). Homemade EM from fruit wastes mixed with worms have better efficiency on the growth of the plant compared to organic fertilizer where the plant showed better growth performance and yield production compared to plants treated with organic fertilizer (Ismail et al., 2012).

Though EM has been widely researched, limited study has emphasized on the production of EM from food waste composting. The objective of this paper is to provide an overview of EM characteristic and its application in food waste composting. The published research related to this topic was reviewed and the characteristics of EM in terms of its microbial content, the multifunction and the application in food waste composting were highlighted. In addition, the quality of compost with EM in terms of the nutrient and heavy metals concentration were also highlighted. The information contributes to the literatures on the efficient composting method using EM, the quality of compost produced and the possible effects to environmental and human health.

2. Materials and Method

This review paper analyzed related studies from 2000 to 2014. All the articles were searched through Scopus and Google Scholar search engines. The keywords used to complete the search for pertinent papers were *"food waste", "compost", "effective microorganisms", "heavy metal compost", "compost duration time''* and *"compost treated with Effective Microorganism''*. The focused of the paper searched was the application of effective microorganisms in food waste composting.

3. Results

Food waste generation

The world loses or wastes one-quarter to one third of food (World Bank, 2014). Statistics have showed that there are large differences in terms of the amount of food waste generated in developed and least developed countries. The percentage of food waste generated in developed country such as Japan, United States, Canada and Germany were two times lesser (14% to 26%) than the amount produced in developing countries (40 to 62%). However, almost 68 to 80% of food waste was produced in least developed countries (i.e. Sri Lanka and Nepal), 3 to 4 times higher than the rest of the countries in the world. The variances on volume of food wasted were related to several factors such as time when most of the food loss (pre and post-harvest, storage, retail, consumption), numbers of labor, technology used, and the difference lifestyle (Bond et al., 2013). For example, more food are lost in least developed countries during pre-harvest process because of the environmental obstacle such as climate and insect. Low type of technology used in the countries had unable to overcome this problem. Besides, during storage food are also lost due to the lack of equipment or facilities needed to store it properly. In contrast, developed countries such as Japan and Germany have appropriate technologies and systems to control the food losses effectively.

Another factor that is related to high food waste being dumped in landfills in least developed countries is the system of waste management that was not very well developed. For instance, municipalities in Nepal have practiced a roadside waste pickup from open piles and open dumping due to technical and financial constraint (Asian Development Bank, 2013). In contrast, most of developed countries such as Europe, has developed a landfill tax system which has reduced the amount of waste disposed in landfill and forced the municipalities to process their ownfood waste. This has reduced the volume of food waste being dumped in the landfill. The tax system also has increased the recycling rate in these countries (European Environment Agency, 2013).

Composting method

Composting is one of the biotechnology process carried by microorganisms such as bacteria, fungi and actinomycetes (Ashraf et al., 2007). Composting process reduced the volume, weight and moisture content of food waste. The putrid smell from the food waste is also minimized (Bachert et al., 2008). Compost also can be a remediation to recover the contaminated soil (Gan et al., 2009; Tandy et al., 2009). Composting give many benefits to the environmental and land management. The process has relatively low capital and operating costs, simple operation and design, and is efficient to reduce organic waste problem (Namkoong et al., 2002).

There are two composting types in which the difference are by the nature of the decomposition process; namely as aerobic and anaerobic (Misra et al., 2003). The characteristics of these composting types are listed in Table 1. Oxygen is present in aerobic composting mainly to break the organic matter in the waste into a stable organic end product such as carbon dioxide, ammonia, water and heat. Anaerobic composting mainly developed an intermediate compound such as methane, organic acid and hydrogen sulphide.

The composting method consists of traditional (Table 2) and rapid composting methods (Table 3) (Misra et al., 2003). In anaerobic decomposition, the materials are allowed to remain in the pit without turning and watering for three months while in aerobic decomposition, the composting process took place by itself without any additional element. In the large scale passive aeration compost method windrow is used to mix the composting materials, to enhance passive aeration and provides conditions congenial for aerobic decomposition. Composting operations may take up to eight weeks while active composting could range take ten to twelve weeks.

As for rapid composting method, the composting process is assisted by additional element such as red worms, effective microorganism or bacteria to break the organic material. This technique produces compost in less than four weeks.

Table 1: The characteristics of aerobic and anaerobic composting.

Characteristic	Aerobic	Anaerobic
Oxygen	Process occur in the presence oxygen	Process occur in the absent or in limited of oxygen supply
Microbe used	Aerobic microbe breaks the organic matter. Stable organic end product produce with Carbon dioxide, ammonia, water, heat and humus.	Anaerobic microbe dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances.
Risk	Little risk of phytotoxicity.	Has strong odors and some present phytotoxicity.
Temperature	The heat generated accelerates the breakdown of organic mater	Low-temperature process
Duration	The processing time is short, depends on the mechanism used (maximum 4 months)	Longer than aerobic composting (6-8 months)
Nutrient value	Nutrients are lost from the composting process	Nutrients did not lost during the process of composting

Source: Food and Agriculture Organization of United Nations, (2003)

Table 2: Traditional composting method

Composting method		Description
Anaerobic decomposition	The Indian Bangalore Method	• Decomposition for a larger part of operations • Requires six to eight months for the operations to complete. • Mostly for treatment of urban wastes.
	Passive Composting of Manure Piles	• Passive composting involves simply stacking the materials in piles to decompose over a long time period with little agitation and management. • The process has been used for composting of animal wastes. • Anaerobic degradation occur including low temperatures, slow decomposition, and the release of hydrogen sulphide and other malodorous compounds.
Aerobic decomposition (Passive aeration)	The Indian Indore Method	• Made at Indore in India by Howard during the period 1924 to 1926. • Consist of pit method and heap method.
	Chinese rural composting	• Consist of pit method and high temperature compost
Large Scale (Passive Aeration)	Passive Windrow Composting	• Natural aeration • Low technology. • Need labor to handle the windrows.
	Turned Windrow Composting	• Mechanical aeration, aerated by a windrow turner • Low technology • Compost in uniform formed compared to passive windrow composting.

Source: Food and Agriculture Organization of United Nations, (2003)

Table 3: Rapid composting method

Composting method	Description
Bin composting	• Simplest in-vessel method. • Eliminate weather problems, contain odours • No turning materials and better temperature control
Rotating drums	• Uses a horizontal rotary drum to mix, aerate, and move the material through the system. • Air is supplied through the discharge end • The drum can be either open or partitioned
Use of Worms (Vermicomposting)	• Used red worms in small up to large scale. • The worm eat all the organic material during the process. • It takes at least 3-4 months to produce compost.
Shredding and frequent turnings	• Compost in a pile • The compost pile was turned to prevent the pile from getting too hot and be aerated. • Material reach optimum temperatures at various times.
Use of Cellulolytic Cultures	• Compost build in pile or bin • Involves inoculating the raw material used for composting with cultures of a cellulose decomposer fungus.
Aerated Static Pile Composting	• The decomposition was assisted by the air that enter the pile through pulling or pushing mechanisms. • Less odor and consumed small space
Rectangular Agitated Beds	• Combines controlled aeration and periodic turning. • A channel on top of each wall supports and guides a compost-turning machine.
Silos	• In-vessel technique resembles a bottom-unloading silo. • The aeration system blows air up from the base of the silo through the composting materials.
Use of Mineral Nitrogen Activator	• Compost build in pile or bin • Nitrogenous fertilizer was added into the center of the pile. • In this high-temperature, bacterially active system, and takes three to four days to produce compost.
Use of Effective Microorganisms (EM)	• Compost build in pile or bin • Effective Microorganisms contain culture of bacteria was added to the raw material to enhance composting process.

Source: Food and Agriculture Organization of the United Nations (2003)

Effective microorganism (EM)

Effective Microorganisms (EM) is a mixture of organisms that has a reviving action on humans, animals, and the natural environment. It has also been described as a multi-culture of 80 ‘coexisting beneficial microorganisms’, which were selected from more than 2,000 species isolated from various environments (Mayer et al., 2010). The main species included in EM are lactic acid bacteria, photosynthetic bacteria, yeasts, actinomycetes and fungi (Xu, 2001). Each of these microorganisms has its own function as listed in Table 4. For example, *Lactobacillus plantarum* may accelerate the decomposition and fermentation in composting process. *Streptomyces albus* produce antibacterial matter for pathogenic bacteria and *Rhodobacter sphaeroides* involve in production of amino acids and amino nucleic (Xu et al., 2000; Sreenivasan, 2013). EM is commercially available. However the exact microbial composition of EM is kept confidential by the manufacturer (Schenck Zu et al., 2009). Daly and Stewart (1999) reported that EM improve crop growth and yield by increasing photosynthesis, producing bioactive substances such as hormones and enzymes, controlling soil diseases and accelerating decomposition of lignin materials in the soil. Some studies have reported that crop growth and yield were increased due to the application of EM (Yan and Xu, 2002; Javaid, 2011). It was also reported that EM can suppress pathogenic microorganisms since the organic acids produced from lactic bacteria are strong sterilizing compounds (Sekeran, 2005).

There also some arguments on the effect of EM application in crop growth and yield. For example, Formowitz et al., (2007) and Daiss et al., (2008) have reported that application of EM has no effects on the crop growth, yield and quality. This was possibly related to short duration of experiment where the effect of EM was only studies for only one crop growth season. Other studies have shown that these drawbacks can be overcome through periodic repeated applications of EM (Formowitz et al., 2007).

EM has been widely used in other field such as in agriculture. It has positive effect on plant development and metabolism (Rasulova et al., 2011; (Lee et al., 2008; Samsudin et al., 2013; Jusoh et al., 2013). EM is used to treat wastewater in environmental field (Zakaria et al., 2010; Anwar et al., 2013; Namsivayam et al., 2011). EM also increased the strength of building in construction (Andrew et al., 2012) and enhanced the livestock production for farmer (Dahal, 2006). EM also has been applied in pest management (Chan et al., 2012).

Table 4: Microorganisms in EM and their function.

Types of Microorganism	Species	Function
Photosynthetic bacteria	*-Rhodopseudomonas palustris* *-Rhodobacter spaeroides*	▪ Production of amino acids, amino nucleic ▪ Bind nitrogen from air ▪ Convert toxic gases
Yeast	*-Saccharomyces cerevisiae* *-Candida utilis*	▪ Promote Fermentation and for plant growth ▪ Produces bioactive substances ▪ Substrate for other EM
Lactic acid bacteria	*-Lactobacillus plantarum* *-L. Casei* *-Streptococcus lactis*	▪ Acceleration the decomposition and fermentation ▪ Suppress & reduce the pathogens
Actinomyteces	*-Streptomyces albus* *-S. griseus*	▪ Produce an antibacterial matter
Fermenting fungi	*-Aspergillus oryzae* *-Mucor hiemalis*	▪ Helps to decompose organic matter ▪ Synthesize amino acids and glucose from carbohydrate. ▪ Control odors

Source: Xu et al, 2000; Xu, 2001; Sreenivasan, 2013; Lindros Whole Earth Consultants, 2014.

Application of EM in organic waste composting

Crop residues and animal wastes have been effectively composted to produce bio fertilizers (Jusoh et al., 2013). Composting material of organic material with effective microbes may improve and or accelerate the composting process (Sharma et al., 2014). Under the effect of selected bacteria, the decomposition of organic substances is faster and particularly, it does not emit gases of offensive smells such as hydrogen sulphide, ammonia, and others (Mwegoha, 2012). The environment is consequently rendered pollution free.

Additives (common nutrients such as starch, cellulose, sugar and vitamin-rich substances, preferably rice bran, sawdust, treacle, slops and oil cake) stimulate the growth of bacteria, particularly cellulose decomposing bacteria, at the initial phase of the decomposition, thereby increasing the capability of decomposing biodegradable organic matters. Combination of additives, EM and cellulose decomposing bacteria also maintains elevated temperature in the composting process. The treatment has low initial investment and operational cost (WIPO, 2007).

Several studies on composting of different organic matter with EM have identified different parameters of temperature, aeration, method of composting and material used to determine the optimum method for production to produce quality compost in short duration of time (WIPO, 2007; Kulcu & Yaldiz, 2004; Huang et al., 2004; Bertran et al., 2004; Cekmecelioglu et al., 2005). Based on these reports, the optimum result of composting process can be achieved under optimum environment. For example, shredding raw material will reduce the time taken for compost to be matured. In addition, the optimum oxygen, temperature and aeration may produce high quality of compost (Nair et al., 2006; Rasapoor et al., 2009; Zhu 2007; Jusoh et al., 2013).

The quality of compost product with EM

Application of EM in composting of organic matter showed positive result in the decomposition process and the mineralization (Saravanan et al., 2013; Mbouobda et al., 2014: Jusoh et al., 2013; Rasapoor et al., 2009). Results show that EM compost had fast decomposition rate, rich in nutrients, more microbial activities, good germination and more yields compared with compost without EM [24, 61]. According to Saravanan et al., (2013), macronutrient Nitrogen in EM compost is higher (1.2%) compared to non-EM compost (0.9%). Phosphorus and organic carbon also was higher in EM compost (1.8% and 5.4%) compare to non-EM compost (1.2% and 5.0%). Besides, the number of Potassium (K) is increased in compost added with EM (55%) compared to in compost without EM (17%) (Jusoh et al., 2013).

EM enriched the compost by means of producing enzymes which act on the organic wastes and enrich the nutrients on the composting process (Saravanan et al., 2013; Mbouobda et al., 2014). According to Daly & Arnst (2005) there was a significant visual difference between compost treatments with and without EM where EM treated compost were fully composted compared to the one without EM.

In other study, EM is used to compost the fruit wastes and the decomposition process was started after the 5th day of EM application by appearance of actinomycetes and fungi growth (Karthick, 2012). A sharp decrease in volume and decolourization, development of pleasant odour, changes in physical texture and less water activity was seen and the process was continue occurring rapidly and complete decomposition was clearly observed on the 25th day, which clearly identified by sharp decrease in volume, complete decolourization, complete absence of water content and complete conversation of fruit wastes into fine powder.

Theoretically, compost treated with EM also will result in low of heavy metals. This is because natural process which relies on bacteria, fungi, and plants alter contaminants such heavy metals as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases (Akhtar et al., 2013). Compost usually contains heavy metals based on their initial raw material. Generally, these heavy metals (micronutrients) are required by the plant for perfect growth and they are absorbed by plants during the fertilizing process; but in large quantities, they can cause phytotoxicity. A report showed that there is an increase of zinc and iron in compost treated with EM but the amount still within the safe limits set by the European Standard for heavy metals in compost, in the range of 210–4000 mg kg^{-1} (Jusoh et al., 2013). Saad et al, (2013) also reported low concentration of heavy metals in EM compost which makes it safe to be used for agriculture. Another study was conducted to test the effects of EM fertilizer in soils contaminated with 30 mg/kg Cr. Results showed that application of EM reduce the chromium accumulation in root and shoot of plants compared to plants without EM fertilizer. The study concludes that EM helps plants to survive in metals toxicity (Dheeba et al., 2014).

Issue and challenge in food waste composting with EM

One of the challenges in food waste composting with EM is the food waste collection. The current food waste management system does not separate the food waste from the general waste. This is especially true in the developing countries as waste segregation activity is not widely practiced (Troschinetz and Mihelcic , 2009; Zhang et al., 2010). The organic waste must be separated for the process to be started. In addition, the community would rather pay higher taxes for waste management authorities to take away their garbage rather than deal with it themselves. Therefore, EM application to degrade the food waste for compost production at home is quite impossible if the public continue to have similar attitude on the handling of their garbage. The challenge is to generate public support for home composting.

Another challenge is the efficiency of EM in food waste composting. Lokare et al (2007) have denied the benefits of EM as there is a great amount of non-reliable information about EM in which the information is always positive about the effectiveness of EM with a clear business oriented targets. EM also was not reliable without homogeneity in the experiment. It also has proven that EM had no clear effect on the quality of the manure and that the yield of a grass was not affected by EM solutions. EM has showed no special effects in the growing of banana plant except for increasing the K concentrations in the leaves (Formowitz et al., 2007).

There is also the issue of competition between organic compost with the huge chemical and industrial manufacturing fertilizer. Synthetic fertilizers have dramatically increased food production worldwide (Mark, 2009). The number of nitrogen fertilizer applied worldwide is more than hundred million tons for every year (Charles, 2013). Comparing with organic compost with EM, chemical fertilizer is more convenient to be applied directly to the plant. There are also some issues with regards to compost and heavy metals content. Naturally, soil contains heavy metals, but the addition heavy metals from compost will lead to negative impact to the soil as well as human health. Plant will absorb the heavy metal from soil and compost. These will be danger to human when they consume the plant.

5. Conclusion

To conclude, although composting is proven to be the solution for food waste management but the practice may pose a challenge. Although all the references highlighted that EM has a great potential to be used in accelerating of composting process, but the mechanism of microbe reaction towards organic waste is prone to certain level of uncertainty which limits this issue from being addressed in most of the references. Thus, the application of EM in food wastes composting need to be studied in further details. The tedious process and time consuming may become the challenge in EM organic composting. Nevertheless, the application of EM in accelerating the composting process may reduce the volume of food waste dispose in landfill if it is successfully conducted.

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CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

ETHICAL ISSUES

None

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